Mercury Air Concentrations in Northern Nevada:

MONITORING ACTIVE METALS MINES AS SOURCES OF MERCURY POLLUTION

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Introduction

Gold mines in northern Nevada are a significant source of mercury air emissions, particularly from a variety of thermal sources at each mine, including roasters, carbon kilns, retorts, autoclaves and furnaces. The US EPA's Toxics Release Inventory (since 1998) and the 2006 Nevada state regulations require mining companies to report their mercury air emissions on an annual basis. In recent years, individual metals mines around the state have reported anywhere from 0 to 9,400 pounds of mercury emissions per year.[1]

However, inconsistencies in data collection lead to questions of the validity of some of these reported numbers. Rigorous source measurements are not required for compliance with TRI reporting (only a best estimate), and, neither the federal or state program currently requires ambient air monitoring to determine mercury concentrations in and around mining facilities. Without an ambient air monitoring program, a reconciliation of total mercury emission reporting with the actual mercury concentrations in air is effectively not possible. Ambient air concentrations are also required to assess impacts of mercury on human health and the environment.

One previous study[2] (Idaho Conservation League, 2005) measured mercury concentrations in air around selected mines. This study found elevated concentrations of mercury downwind from certain mines, compared to ambient air upwind or distant from the mines. In at least one case, ambient mercury concentrations were observed to be over 100 times background concentrations.

The purpose of the present study is to determine if a readily available and field transportable instrument would be useful for determining mercury concentrations in ambient air, particularly around gold mines. We also sought to determine if the concentrations of mercury in ambient air around gold mines are sufficiently elevated to obtain useful data, compared to background sites?

In order to answer the above questions an instrument was selected, and a series of trips were taken in northern Nevada to assess the utility of the instrument and to measure ambient mercury concentrations in air at several sites in northern Nevada.

Instrument

The instrument used to collect instantaneous levels of mercury in ambient air was an RA-915+ Zeeman Spectrometer, rented from Ohio Lumex of Twinsburg, OH. A one-day training course was taken and proper maintenance according to the manual was performed. This instrument has an internal calibration source, and does not require external standards. The EPA reported the following in a May 2004 evaluation of the instrument:

> "The RA-915+ Mercury Analyzer is a portable AA spectrometer with a 10-meter (m) multipath optical cell and Zeeman background correction. Mercury is detected without preliminary accumulation on a gold trap. Mercury samples are heated to 750-800°C, causing organic materials to be decomposed and mercury to be vaporized in a carrier gas of ambient air. The airflow carries the vaporized mercury to be carried to the analytical cell . The RA-915+ includes a built in test cell for field performance verification. The operation of the RA-915+ is based on the principle of differential, Zeeman AA spectrometry combined with high frequency modulation of polarized light. This combination eliminates interferences and provides the highest sensitivity. A mercury lamp is placed in a permanent magnetic field in which the 254-nm resonance line is split into three polarized components, two of which are circularly polarized in the opposite direction. These two components (σ- and σ+) pass through a polarization modulator, while the third component (π) is removed. One σ component passes through the absorption cell; the other σ component passes outside of the absorption cell and through the test cell. In the absence of mercury vapors, the intensity of the two σ components are equal. When mercury vapor is present in the absorption cell, mercury atoms cause a proportional, concentration-related difference in the intensity of the components. This difference in intensity is what is measured by the instrument.[3]

The elimination of background interference, portability, and low detection limit made the RA-915+ a useful instrument for this project. This instrument continuously monitors elemental mercury concentrations in air and reports concentrations of mercury each second.

Limitations

Measurements were limited to areas where public access was available. Thus, we were not always able to access locations directly downwind from some facilities, or take measurements at similar distances from each operating facility. Similarly, information was not available concerning operating hours of processing facilities, so we were not able to coordinate measurements with times when processing facilities were in operation or at peak operation. While atmospheric mercury can exist in particulate, divalent, or elemental forms, the elemental form is almost always the predominant form. It is also the only form measured with this instrumental configuration. Finally, the measurements reported here represent snapshots of elemental mercury concentrations in ambient air, and were not designed to provide quantitative information on mercury release from individual mine sites.

Background Concentrations and Naturally Elevated Mercury Concentrations

Background concentrations of mercury were determined in locations distant from developed areas and not in close proximity to any mines or geothermal areas. While the instrument has a limit of detection of 2 ng/m^3, some variability was observed at those concentrations, and a conservative limit of quantitation was used of 5 ng/m^3. None of these average ambient mercury determinations at background sites were greater than 5 ng/m^3.

Mercury is also emitted into the air naturally by hot springs and other geothermal activities. Readings taken directly from the plume at Nightingale Hot Springs, areas around Steamboat hot springs and at Brady Geothermal gave readings below. In all of these cases, mercury concentrations were significantly elevated, compared to the background concentrations of less than 5 ng/m^3.

Mercury Concentrations in Ambient Air Near Nevada Gold Mines

Following are the data sets collected at various mine sites. Data sets were collected as above, and are presented in the same manner. As a visual aid, points representing a single reading or an entire data set were plotted on the photographs obtained from GoogleEarth[4]. Minute long intervals were taken, which were averaged, and maximum and minimum concentrations observed during that minute were also reported. Measurements of mercury concentrations in air taken at the startup at each site often gave anomalous high or low values; these are excluded and measurements are only reported when the instrument had stabilized after a warm-up, generally 5–15 minutes. Each sampling process consisted of a driver and a passenger who operated the instrument. Typically the intake hose was fastened out the window or held by hand to receive outside ambient air. Summer temperatures ranged from 24–33°C.

all mercury concentrations in ng/m^3

Date	Location	Max, ng/m^3	60sec average	Min,ng/m^3
8/1/2006	Brady Geothermal	6.7	5.1	1.5
8/1/2006	Nightingale Hot Springs	15.2	6.8	1.1
8/3/2006	Steamboat Hot Springs	21.7	13.9	8
8/3/2006	Steamboat Geothermal	43.6	34.1	26.7

Florida Canyon

Operated by: Jipangu, Inc.
Lat/Long: 40°35′N / 118°14′W[5]

Florida Canyon Mine was accessed from I-80, exit 138. The monitoring was done on a frontage road that ran along the freeway and the access road to the employee parking lot. On this initial sample, GPS was not used to correlate data with location. Slight elevations of mercury concentrations were observed in the parking lot, but no elevated concentrations on the access road. In this instance, downwind samples were inaccessible to the east.

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Ave	Min	Winds	Notes	Key
8/1/2006	Florida Canyon	1	8.1	6.8	5.9	W	inaccessible	(inset)

Coeur-Rochester

Operated by: Coeur Rochester, Inc.
Lat/Long: 40°17′N / 118°09′W[5]

At Coeur-Rochester, several measurements were taken to associate the sources of mercury found in the air. The road leading to the mine, which lies in a general upwind direction, was found to have background concentrations of < 5ng/m^3. Concentrations of mercury increased when we first entered the valley in which the mine was located. Two sets of measurements were taken at this mine during two visits. On the first trip, highly elevated concentrations (>2000 ng/m^3) were measured in the employee parking lot. Elevated concentrations were also measured along the road, as well as on the unpaved road north of the adjacent wet leach pads (indicated by the blue, orange and yellow dots on the inset below). During the second trip, elevated concentrations adjacent to the wet leach pads were found to have much higher emissions than their dry counterparts, along the northern rim of the mine. No highly elevated concentrations were observed in the parking lot during the second visit.

We had no information on the operational differences of the mine between the first and second visits. Also, the geography of the valley was such that wind direction and speed changed often, although the wind on both visits was generally low.

For this sampling, GPS correlation of data was unavailable. Monitoring of heap leach pad was carried out on a dirt road north of the facility, as indicated above by a black line. Image by SkyTruth.[5]

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Ave	Min	Winds	Notes	Key
8/1/2006	Coeur-Rochester	1	2326.3	1618.7	410.0	Variable	parking lot	red
8/1/2006	Coeur-Rochester	2	214.8	80.2	36.8	Variable	active pad	blue
8/15/2006	Coeur-Rochester	3	15.0	10.0	7.3	Variable	dry pad	orange
8/15/2006	Coeur-Rochester	4	62.2	40.9	31.6	Variable	active pad	yellow

Lone Tree

Operated by: Newmont Mining Corp.
Lat/Long: 40°50′N / 117°12′W[5]

Lone Tree Mine was visited twice, with similar results. The mine was accessed via Exit 212 from I-80. We were unable to get directly downwind from the mine, and ambient concentrations were measured only along the road and employee parking lot. On the second visit, stacks were observed to be active, but downwind areas were not accessible. All of the averaged concentrations were not substantially greater than background concentrations.

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Ave	Min	Winds	Notes	Key
8/7/2006	Lone Tree	1	16.4	7.7	2.8	SE	inaccessible	(inset)
8/15/2006	Lone Tree	2	9.2	7.5	5.7	NW	not shown	n/a

Marigold

Operated by: Glamis Gold Ltd.
Lat/Long: 40°44′N / 117°08′W[5]

Monitoring near the Marigold Mine was conducted along the road leading to the facility. Slight elevations were observed on the outer road leading to the mine. Higher concentrations were observed along the road, and very high concentrations (>3000 ng/m^3) were measured in the parking lot. The parking lot was located directly downwind from the processing facility at the Marigold Mine on the initial visit.

A second visit to the Marigold mine was conducted on 8/15/06 (not included in diagram). During this visit, elevated concentrations were not observed. However, air movement away from our location precluded a downwind measurement.

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Ave	Min	Winds	Notes	Key
8/7/2006	Marigold	1	3139.7	1463.1	376.8	SE	parking lot	(inset)
8/15/2006	Marigold	2	20.6	15.0	10.7	NW	not shown	n/a

Phoenix Mine

Operated by: Newmont Mining Corp.
Lat/Long: 40°31′N / 117°07′W[5]

The Phoenix Mine is located southwest of Battle Mountain, off the main highway. An access road was used in an attempt to reach the facility, but the gate at Phoenix precludes access to the facility.

all mercury concentrations in ng/m^3

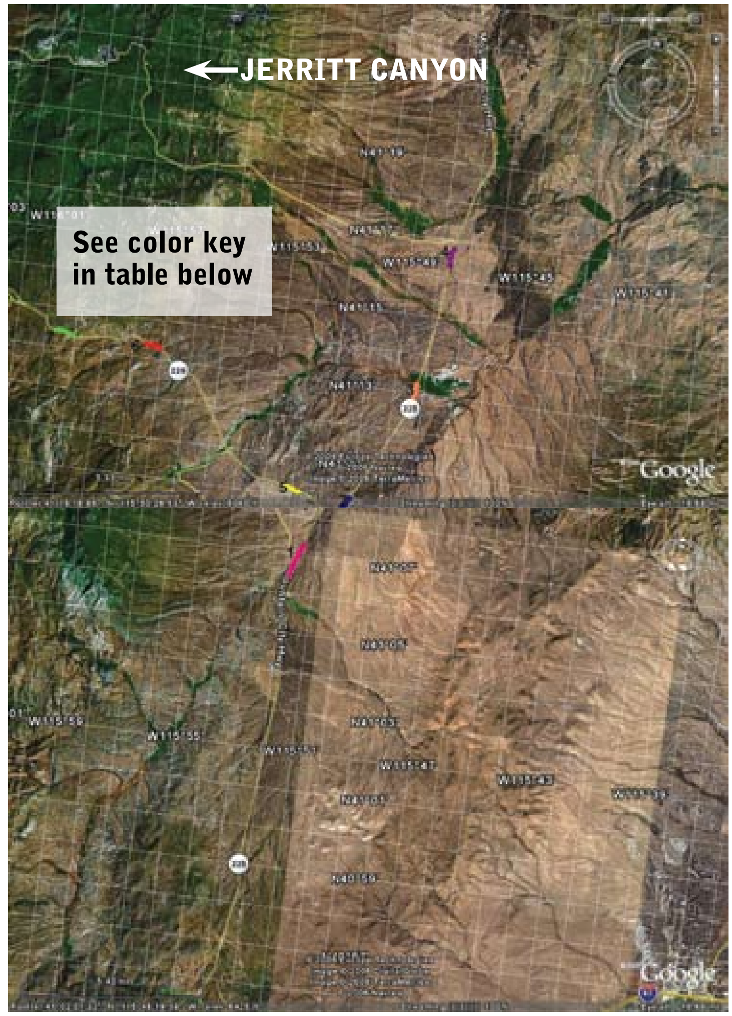
Date	Site	Data Set	Max	60s Ave	Min	Winds	Notes	Key
8/7/2006	Phoenix	1	7.1	2.8	0.3	SE	inaccessible	(inset)

Jerritt Canyon

Operated by: Queenstake Resources Ltd.
Lat/Long: 41°23′N / 116°00′W[5]

Jerritt Canyon is located north of Elko, along Route 225, the Mountain City Highway. On two separate occasions, elevated concentrations were observed in the ambient air while driving north along Route 225.

Seven 60 second averages were taken along the two highways. In the map below, Jerritt Canyon can be seen in the top, left-hand corner. Route 225, which lies in a general downwind direction from Jerritt Canyon, gave elevated concentrations until we reached as far north as 41°30'N latitude (off the diagram to the north). Concentrations consistently above 10 ng/m^3 were measured on Route 225 directly to the east and south east of Jerritt Canyon (see data sets 1–4). Along Route 226, higher concentrations were measured than on Route 225 (see data set 5). At around 115°59' W, the mercury concentrations decreased to background concentrations, as shown by data set 7.



all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Avg	Min	Winds	Key
8/11/2006	Jerritt Canyon (Rt225N)	1	18.7	17.5	16.0	W	pink
8/11/2006	Jerritt Canyon (Rt225N)	2	14.6	13.2	12.0	W	blue
8/11/2006	Jerritt Canyon (Rt225N)	3	13.4	12.4	11.1	W	orange
8/11/2006	Jerritt Canyon (Rt225N)	4	13.6	12.6	11.6	W	purple
8/10/2006	Jerritt Canyon (Rt226W)	5	19.2	14.3	9.7	NW	yellow
8/10/2006	Jerritt Canyon (Rt226W)	6	32.7	31.3	29.3	NW	red
8/10/2006	Jerritt Canyon (Rt226W)	7	4.8	3.1	1.2	NW	green

Gold Quarry (South Carlin)

Operated by: Newmont Mining Corp.
Lat/Long: 40°47′N / 116°11′W[5]

The Gold Quarry Mine is located just off of Route 766, northwest of Carlin, NV. Monitoring was conducted on Route 766, as well as on the road leading to the parking lot at the mine. Elevated concentrations were observed along the main road (see data sets 2, 4, 5) and the highest adjacent to a leach pad (see data sets 3–4).

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	Ave	Min	Winds	Key
8/10/2006	Gold Quarry	1	7.5	4.8	3.4	NW	lt. blue
8/10/2006	Gold Quarry	2	30.9	10.4	7.3	NW	orange
8/10/2006	Gold Quarry	3	47.3	23.6	9.7	NW	red
8/10/2006	Gold Quarry	4	13.5	10.4	8.9	NW	purple
8/10/2006	Gold Quarry	5	17.5	13.5	8.0	NW	green

North Carlin

Operated by: Newmont Mining Corp.
Lat/Long: 40°57′N / 116°22′W[5]

The North Carlin mine complex is accessed by Route 766, traveling north from Carlin, NV. Background concentrations were observed for the majority of the monitoring, mostly south of the heart of the complex. The highest concentration recorded (data set 3) was found adjacent to an active leach pad. The mercury measurements at this site may have contributions from the adjacent Goldstrike Mine, but no attempts were made to separate sources.

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	Ave	Min	Winds	Key
8/10/2006	North Carlin	1	4.8	3.0	1.2	NW	blue
8/10/2006	North Carlin	2	4.4	2.9	1.6	NW	yellow
8/10/2006	North Carlin	3	25.9	11.2	4.3	NW	red
8/10/2006	North Carlin	4	13.5	8.9	4.2	NW	orange

Cortez Mine

Operated by: Barrick Gold Corp.
Lat/Long: 40°15′N / 116°42′W[5]

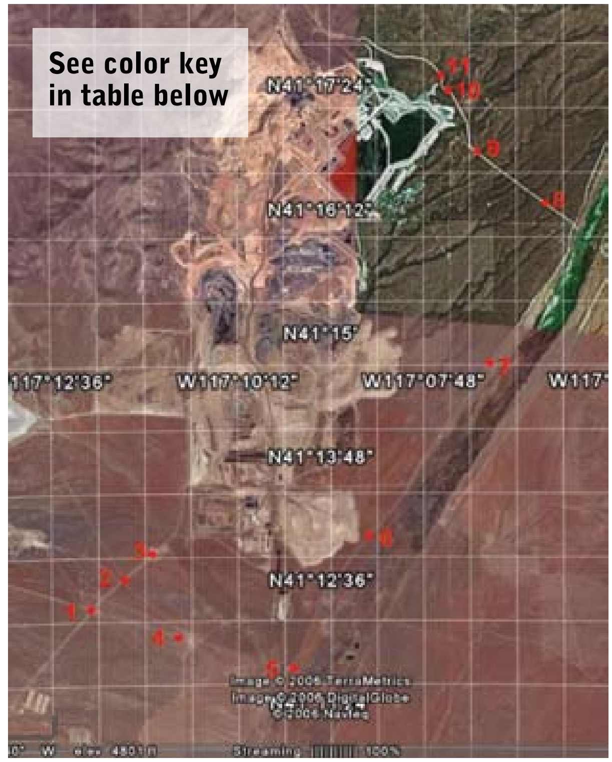
The Cortez Mine (Pipeline) is located in Crescent Valley, NV, and is accessed via Route 306. A wind from the northwest suggested the leach pad at Cortez Mine as a potential source of mercury in the area. Upwind samples, taken to the north of the facility (see data sets 1–2) were only slightly elevated in mercury concentrations. As we moved downwind the concentrations increased, with a peak concentration directly south of the mine (see data sets 3–7).

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	Ave	Min	Winds	Key
8/10/2006	Cortez	1	19.5	6.2	0.5	NW	pink
8/10/2006	Cortez	2	13.5	8.6	5.3	NW	blue
8/10/2006	Cortez	3	32.4	26.0	16.4	NW	green
8/10/2006	Cortez	4	24.1	22.9	21.7	NW	orange
8/10/2006	Cortez	5	31.4	28.7	26.6	NW	black
8/10/2006	Cortez	6	46.4	40.2	36.4	NW	red
8/10/2006	Cortez	7	37.0	34.8	33.0	NW	yellow

Twin Creeks

Operated by: Newmont Mining Corp.
Lat/Long: 41°16′N / 117°10′W[5]



The Twin Creeks Mine is located to the northeast of Golconda, NV. The mine was approached from the south, although access to the site reading required travel on several minor roads. The processing facility was visible on the north end of the mine, and a downwind measurement of mercury was obtained. Elevated concentrations were observed for the majority of the area surrounding the mine to the south and southeast. Once downwind of the visible stack emission, substantial increases in atmospheric mercury concentrations were observed. A peak of 693.7 ng/m^3 was noted at a distance approximately 1.75 miles away from the Sage Mill (calculated using GPS coordinates).[2] Once north of the stack emission, concentrations began to fall.

Due to the low quality of the image, as well as the large scale, data sets were plotted on the map of Twin Creeks using only a point and a corresponding number to show approximate location. Data sets marked with asterisks were verified using GPS.

all mercury concentrations in ng/m^3

Date	Site	Data Set	Max	60s Ave	Min	Winds	Key
8/12/2006	Twin Creeks	1	15.1	13.3	11.8	W-NW	1
8/12/2006	Twin Creeks	2	15.5	12.9	11.0	W-NW	2
8/12/2006	Twin Creeks	3	14.5	12.6	10.2	W-NW	3
8/12/2006	Twin Creeks	4	12.2	11.1	9.9	W-NW	4
8/12/2006	Twin Creeks	5	11.7	10.2	8.7	W-NW	5
8/12/2006	Twin Creeks	6	12.5	10.7	9.1	W-NW	6
8/12/2006	Twin Creeks	7	25.2	20.6	15.4	W-NW	7
8/12/2006	Twin Creeks	8*	41.9	28.3	20.6	W-NW	8
8/12/2006	Twin Creeks	9*	142.8	55.1	17.9	W-NW	9
8/12/2006	Twin Creeks	10*	694.7	258.7	54.8	W-NW	10
8/12/2006	Twin Creeks	11*	38.8	21.1	12.6	W-NW	11

Conclusions

Ambient mercury concentrations were measured downwind from ten gold mines in northern Nevada. Spot sampling revealed mercury concentrations significantly higher than detection limits and background levels at seven of these facilities. The performance of the mercury determination instrument for this brief study was very good and indicates that the instrument can yield useful results and be operated with minimal training. Thus, it has applications for use by mining companies for at routine monitoring of mercury concentrations in air for purposes of protection of worker health, as well determining ambient air concentrations at the open-air mine sites.

The highest 60 second averaged ambient air mercury concentrations were measured at the Twin Creeks (259 ng/m^3; maximum of 694 ng/m^3), Coeur Rochester (1619 ng/m^3; maximum of 2326 ng/m^3) and Marigold mines (1463 ng/m^3; maximum of 3120 ng/m^3). These elevated concentrations (compared to background concentrations of <5 ng/m^3) tended to occur directly downwind from processing facilities. The lowest ambient air mercury concentrations were measured at the Florida Canyon and Lone Tree mines, with mercury concentrations not substantially different from background concentrations. While these measurements were not designed to comprehensively determine mercury concentrations in air within a mine site, it was clear that the concentration of mercury was highly dependent on the wind direction as well as the proximity to operating facilities. Highest concentrations were determined downwind from processing facilities, while much lower concentrations (near background) were determined upwind from each mine. These concentrations were much higher than expected and approach concentrations where impacts to worker health and safety, particularly to women of child bearing age, should be assessed.

Actively leached cyanide heaps were found to be potentially large sources of release of mercury into the atmosphere. Particularly at the Coeur Rochester heap, elevated concentrations were observed near wet (active) portions of the heap, while dry sections had much lower concentrations. These heaps are presently an unrecognized source of mercury release to the atmosphere, and this source, as well as tailings facilities and waste rock dumps may be significant sources of fugitive emissions.

Recommendations

We make the following recommendations:

1. This specific instrument, the Lumex RA-915+ Mercury Analyzer, was found to be very useful for measuring elemental mercury concentrations in air. Further study is recommended to compare this instrument with others that are suitable for field measurements. The goal should be to have a robust but cost-effective set of methods for determining mercury in ambient air. These measurements can be used for ambient monitoring to identify whether worker health and the environment are protected from mercury releases from mining sites.

2. In part, due to suggestions that frequent measurement of ambient mercury concentrations and emission sources is too expensive, routine mercury measurements have not been required. However, this set of measurements, albeit only a snap shot, demonstrated a relatively simple elemental mercury measurement technique that required less than one day of training, and was easily used in the field. This instrument would allow each mine the capability for routine (weekly or more often) measurements of elemental atmospheric mercury. State and federal regulatory agencies can also use these instruments for compliance purposes.

3. Further research is necessary to determine the total amount of mercury released from a mine site, particularly from active heaps, but also from waste rock dumps, tailings facilities and pit wall surfaces. Unlike thermal sources which generally emit as a point source, a large heap can be several hundred acres, and emit mercury continuously, although it will certainly vary with environmental conditions. These non-thermal sources are not characterized at present and not included in total mercury emissions from mines, but should be.

4. Because of the simplicity of these measurements, they show promise for validating modeling efforts for mercury release from a mine site. While it is effectively impossible to determine concentrations of mercury in all of the air mass downwind from a mine, simple measurements can validate models by collecting the necessary meterological data as well as mercury concentrations at selected points. This procedure would greatly assist in allowing a determination of whether all sources of mercury from a mine site were being considered. It could also help to allow regulators to make more reliable estimates of total mercury released at a mine site.

References

1. EPA Toxics Release Inventory, August, 2006, http://www.epa.gov/tri/.
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4. Google Earth, Version 4.0.2091; September 14, 2006.
5. InfoMine, http://www.infomine.com; September 2006.

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